The role of WSS in in-stent restenosis

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Introduction

Atherosclerosis may lead to partial or total occlusion of an artery, most often occurring in the coronary arteries leading to myocardial infarction. The common treatment is the insertion of a stent which can, however, induce a local patho-physiological remodelling process known as in-stent restenosis. It has been proved that regions prone to atherosclerosis experience a low Wall Shear Stress (WSS < 0.5 Pa) compared to protected areas (WSS > 1.2 Pa) *[Malek et al, 1999]*. The aim of this study is to test whether a shear stress-driven remodelling scenario can explain in-stent restenosis patterns. In this study, a WSS lower than or equal to 0.5 Pa is taken as binary threshold to trigger the remodelling process.

Methods

PyFormex *[http://pyFormex.berlios.de]* is an open source software under development at Ghent University dedicated to pre- and post-processing both in FEA and CFD problems. An axisymmetric geometry of stented arterial lumen has been designed in pyFormex and meshed with quadrilateral elements (1413 nodes), as illustrated in Fig.1.

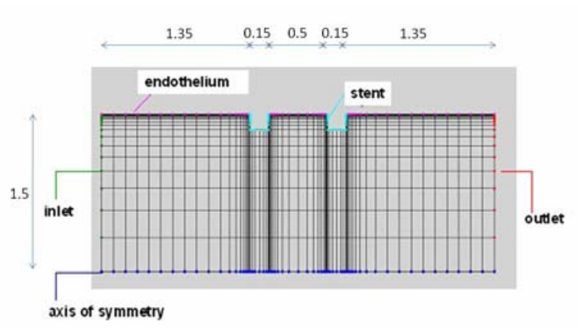

Fig.1 – *Axisymmetric model of stented artery*

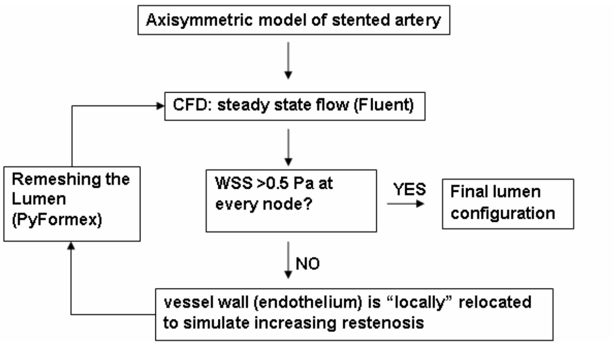

Fig.2 – *WSS-based iterative procedure to simulate restenosis*

The basic axisymmetric section represents a portion of an artery with length 3.5 mm and radius 1.5 mm on which there are 2 stent struts with side 0.15 mm and inter-strut distance 0.5 mm. A steady state parabolic profile (Vmax=1 m/s) has been applied to the inlet. The evolution of the restenosis as local reduction of lumen patency has been simulated in a loop as described in the scheme in Fig.2.

Results

In Fig.3 the initial and an intermediate (after 35 iterations) lumen geometries are illustrated. The sites of greatest remodelling are the ones on the sides of the stent struts, both proximal and distal, which correspond to lowest velocity gradient (the density of isolines decreases in this area). Different strut sizes have been tested and convergence was always reached.

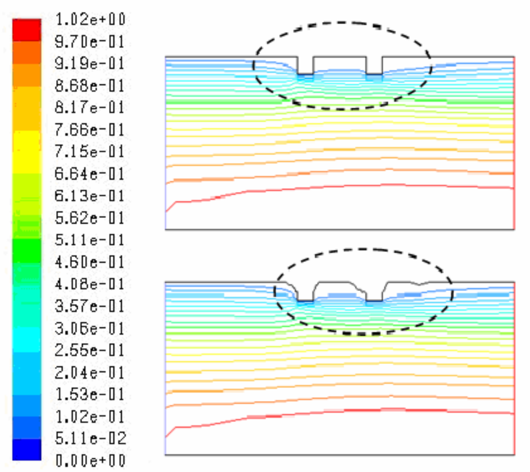

Fig.3 – *Isolines of Velocity Magnitude (m/s) at the initial configuration (TOP) and after 35 iterations. (BOTTOM)*

Conclusions

The present numerical study describes an active adaptation framework of a living vessel in response to an altered wall shear stress stimulus due to the presence of a stent following a mechano-biological approach. Although the followed approach is simple, it is able to predict that the restenosis develops in the immediate vicinity (proximal and distal) of the stent struts, as clinically observed. Future work will focus on including more complex (biological) stimulus-response feedback algorithms (e.g. drug eluting stents) *[Kolachalama et al, 2009]*.